CORROSION PROTECTION FOR WINDMILLS

ONSHORE AND OFFSHORE

By Karsten Mühlberg, Hempel (Germany) Ltd., Cologne (Germany)

SUMMARY

It is described on which basis of standardization the corrosion protection for windmills, erected on land and in the sea, can be regulated and realized. Two essential standards are introduced. The **EN ISO 12944** „Paints and varnishes – Corrosion protection of steel structures by protective paint systems (1998) and the **NORSOK M 501**, Surface Preparation and Protective Coating (5. Revision 2004). Reference coating systems are named and their requirements and criteria for approval are described. Differences between on- and offshore exposure for windmills are explained. The need for highly qualified execution of the corrosion protection works, especially for offshore matters, is underlined. The role of the quality assurance/ quality control in this regard is highlighted. References of successfully realised objects on land and in the sea are given.

1. INTRODUCTION

Around 15.800 windmills with a capacity of 15.329 Megawatt have been installed in Germany only on land until July 2004. It meant, many millions square meters of mainly steel had to be protected. A steel tower for a e.g. 5 MW wind turbine has an area of up to 3000-4000m². And now, the wind industry is moving offshore, big projects are in the pipeline. Windmill turbines are regarded as objects with a life time of 20-25 years. The designed corrosion protection has also to last at least that time without general maintenance. Due to their type of construction, steel towers with a height of the nacelle of up to more than 100 meters and due to their typical location, either on sea or on land often in areas with low infrastructure, the access for later works on the turbines is difficult and costly. And windmill turbines have also to fulfil a certain aesthetically function and they are very often subject of public discussions. Therefore is it of utmost importance, that the corrosion protection is of very high quality. That means, the relevant works in the factories in question have to be organised, carried out and supervised/ controlled in a very professional way on a very high level. Paints have to be tailor made for the needs of the different manufactures of steel towers. Taking these points not into account, will result in a not acceptable quality of the corrosion protection. Defects related to this will soon or longer influence the operational availability, will cause loss of earnings, are often soon visible (on exterior areas) and may influence the image negatively.

2. RELEVANT STANDARDS

How is nowadays a modern corrosion protection especially for windmills regulated?
Out of numerous standards two essential ones shall be emphasized:

1. EN ISO 12944 „Paints and varnishes – Corrosion protection of steel structures by protective paint systems (1998)
2. NORSOK M 501, Surface Preparation and Protective Coating (5. Revision 2004).

The 1998 introduced EN ISO 12944 is valid worldwide and presently **"the standard".** It regulates the corrosion protection from minor aggressive environments like interior areas, to rural climate up to city and industrial atmosphere as well as steel constructions (e.g. bridges) at the coast and offshore. Corrosion protection for hydraulic steel works (steel structures in immersion service) and galvanized steel is described also in the EN ISO 12944. The standard contains furthermore indications about the lifetime of the various systems.

EN ISO 12944 (1998), 8 parts

Part 1:	General introduction	General definitions, health and safety and environment protection, protection times
Part 2:	Classification of environments	Corrosivity categories for atmosphere, water and soil, loss of mass of steel and zinc by corrosion in different environments
Part 3:	Design consideration	Design criteria for steel structures to improve their resistance to corrosion
Part 4:	Types of surface and surface preparation	Methods of surface preparation for different surfaces, cleanliness grades and roughness of surfaces

Part 5:	Protective paint systems	Different generic types of paints, paint systems for all corrosivity categories for different protection times
Part 6:	Laboratory performance test methods	Preparation and evaluation of test panels, test methods for paint systems for all corrosivity categories
Part 7:	Execution and supervision of paint work	Methods of application of paint materials, guidelines for application in workshop and on site, preparation of reference areas
Part 8:	Development of specifi-cations	Guidance for developing of different specifications for corrosion protection works (new building and maintenance)

NORSOK M- 501 (5. Revision 2004)
This standard was developed by "Norwegian Technology Standards Institution" (Oscarsgt. 20, Postbox 7072 Majorstua N-0306 Oslo, NORWAY) with assistance by the Oil and Gas exploring and processing industry. It describes merely but detailed the corrosion protection of respective offshore-installations. The standard can be loaded down, without costs from website www.nts.no/norsok. **Excerpt from content:**

4 .	General Requirements	Notes to application conditions, coating and steel materials, shop primers, pre-qualification of products, personnel and procedures
6.	Surface Preparation	Pre blasting preparations (edges, welding seams etc.), blast cleaning, final surface condition
7.	Paint Application	Notes to application equipment and application
8.	Thermally Sprayed Metallic Coatings	Materials, application, repair
9.	Sprayed on Passive Fire Protection	Materials, application, repair
10.	Qualification Requirements	Pre-qualification of products, qualification of personnel and procedures
11.	Inspection and Testing	Methods for inspection and testing and criteria's for acceptance
	ANNEX A	Paint systems for different areas for offshore facilities

A last note regarding the offshore- standards: Since November 2003 a new ISO- standard for offshore matters has been released. It is called ISO 20340: Paints and varnishes - Performance requirements for protective paint systems for offshore and related structures (11/2003). The objective of this standard are laboratory test methods and evaluation criteria for coating systems for steel structures (new building) exposed to offshore environments. The environments in question are the C5- marine and the Im 2 according to the ISO 12944, part 2. The 5. revision of the NORSOK M 501 is using the ISO 20340 for testing and approving of paint systems.
A number of NACE publications also exist on the subject of offshore coatings and presently a number of standards prescribing test methods and recommended qualification criterias are currently being developed for the different areas that are relevant on offshore structures.

3. CORROSION PROTECTION FOR WINDMILLS ON LAND (ONSHORE)

Decisive for the choice of a reliable corrosion protection is the expected corrosion attack of the environment around the location of the windmill and the desired lifetime. The classification of our environment in this respect can be taken from EN ISO 12944 part 2. Five corrosivity categories are defined from (C1) not corrosive interior atmosphere up to industrial and sea-climate (C5 I + C5 M). I stands for industry, M stands for marine. Decisive for the determination of the categories is the loss of mass of unprotected steel and galvanized steel at outdoor storage (see table 1). IM1 to IM3 describe the load in water and soil. IM stands for immersion.

Illustration 1: Statement of EN ISO 12944, part 2, corrosivity categories C3,4 and 5 as well as Im 1-3 (excerpt).

Table 1: Atmospheric corrosivity categories and examples of typical environments						
Corrosivity category	**Mass loss per unit surface/ thickness loss (after first year of exposure)**				**Examples of typical environments in a temperate climate**	
	Low carbon steel		**Zinc**		**Exterior**	**Interior**
	Mass loss g/m²	**Thickness loss µm**	**Mass loss g/m²**	**Thickness loss µm**		
C3 medium	> 200 to 400	> 25 to 50	> 5 to 15	> 0,7 to 2,1	Urban and Industrial atmospheres, moderate SO2 pollution, coastal areas with low salinity.	Production rooms with high humidity and some air pollution, e.g. food processing plants, breweries, laundries.
C4 high	> 400 to 650	> 50 to 80	> 15 to 30	> 2,1 to 4,2	Industrial and coastal areas with moderate salinity.	Chemical plants swimming pools. Coastal ship- and boatyards.
C5 M (marine) very high	> 650 to 1500	> 80 to 200	> 30 to 60	> 4,2 to 8,4	Coastal and off-shore areas with high salinity.	Buildings or areas with almost permanent condensation and high pollution.

Table 2: Categories for water and soil		
Category	**Environment**	**Examples of environment and structures**
IM 1	Fresh water	River installations, hydro- electric power plants.
IM 2	Sea or brackish water	Harbour areas with structures like sluice gates, locks, jetties. Offshore structures.
IM 3	Soil	Buried tanks, steel piles, pipes.

Planning and realisation of windmill farms in Germany is done almost exclusively in areas with rural to city-like character. The erection in industrial areas (e. g. in chemical plants) is rare. The now applying corrosivity category complies with C3 (moderate load, see illustration 1). Is a generally maintenance free lifetime (protection time) of more than 15 years of the coating system expected, the EN ISO 12944 recommends in part 5 various multi-coat systems with a dry film thickness from 160 - 240 µm.

Illustration 2: Statement from EN ISO 12944, part 5, paint system for corrosivity category C3 (excerpt).

Paint System No.	Surface preparation grade		Priming coat(s)				Top coat(s) including intermediate coat(s)			Paint system		Expected durability (see 5.5 and ISO 12944-1)		
	St2	Sa2½	Binder	Type of primer	Number of coats	NDFT µm	Binder	Number of coats	NDFT? µm	Number of coats	Total NDFT µm	Low	Medium	High
3.15		X	EP		1	160	AY	1	40	2	200	■	■	■
3.16		X			1-2	80	EP, PUR	1	40	2-3	120	■		
3.17		X			1-2	80		1-2	50	2-4	160	■	■	
3.18		X			1-2	80		2-3	120	3-5	200	■	■	■
3.19		X			1-2	80		2-3	160	3-5	240	■	■	■
3.20		X	EP, PUR	Zn(R)	1-2	80	-	-	-	1-2	80	■	■	
3.21		X	EP, PUR		1	40	EP, PUR	1	120	2-3	160	■	■	■
3.22		X			1	40		2-3	160	3-4	200	■	■	■
3.23		X			1	40	AY,CR,PVC	1-2	120	2-3	160	■	■	
3.24		X			1	40		2-3	160	3-4	200	■	■	■
3.25		X	ESI		1	80	-	-	-	1	80	■	■	

The in illustration 2 given definitions regarding expected time of protection (durability)
short (2 - 5 years), **middle (5 - 15 years)** **and long (> 15 years)**
are no guarantee terms but the period to the first planned maintenance regarding corrosion protection. They therefore help to choose coating systems in respect of their lifetime.

A typical coating system for onshore windmills is nowadays a 3-coat system consisting of:

2 comp. epoxy-zinc rich primer	**50**	**-**	**80**	**µm**
2 comp. epoxy mid coat	**100**	**-**	**150**	**µm**
2 comp. polyurethane topcoat	**50**	**-**	**80**	**µm.**

Possible are also efficient 2-coat systems like e.g.

2 comp. epoxy-zinc rich primer	**80**	**µm**
2 comp. polyurethane topcoat	**120**	**µm.**

At the classical and mainly used 3-coat system, most in the market found specifications show often film thicknesses from 240 to 280 µm whereby the last mentioned almost matches the requirements of the highest corrosivity category C5 (industry). Due to the reasons already mentioned (long lifetime without maintenance, limited access, location at the coastline) this safety margin is acceptable. But 200 µm outside and 160 µm inside (for steel towers) should be the lowest limit for onshore installed wind turbines. The recommended values are in the first rank related to components exposed to steady weathering like the exterior of the steel towers or hubs. Other parts of the windmill (generator, gearbox, rotor shaft, main frame etc.) and the tower inside may be protected analogous, but lower film thicknesses are possible as during operation of the windmill the dew point is seldom met (within the nacelle) and some other parts will never have atmospherically contact.

4. CORROSION PROTECTION FOR WINDMILLS ON SEA (OFFSHORE)

With the corrosivity category C3 (moderate load acc. to EN ISO 12944, part 2) the requirements for corrosion protection of onshore installed windmills have been defined. C5-M (high corrosivity, sea, see table 1) characterized the conditions to which offshore windmills are exposed to. Im 2 (also part 2, EN ISO 12944) describes permanent exposure to water (seawater and brackish water). The EN ISO 12944 recommends as coating systems multi-coat applications from 320 up to 500 µm (atmospheric exposure C5-M) and 480 up to 1.000 µm (immersed, Im 2). These statements are valid for almost maintenance free periods of corrosion protection exceeding 15 years.

Illustration 3: Statement from EN ISO 12944, part 5, paint system for corrosivity category C5 (excerpt).

Paint System No.	Surface Preparation grade	Priming coat(s)				Top coat(s) including intermediate coat(s)			Paint system		Expected durability (see 5.5 and ISO 12944-1) C5-I			C5-M		
	Sa2½	Binder	Type of primer	Number of coats	NDFT µm	Binder	Number of coats	NDFT µm	Number of coats	NDFT µm	L	M	H	L	M	H
S5.01	X	CR	Misc.	1-2	80	AY,CR,PVC	2	120	3-4	200	■			■		
S5.02	X	EP,PUR		2	120		1-2	80	3-4	200	■	■				
S5.03	X	ESI	ZN(R)	1	80		3	200	4	280	■	■	■	■	■	
S5.04	X			1	80		4	240	5	320	■	■	■	■	■	
S5.05	X	EP,PUR		1	40	EP+CR	2	200	3	240	■	■		■	■	
S5.06	X			1	40	EP, PUR	3-4	280	4-5	320	■	■	■	■	■	
S5.07	X			1	40		2	120	3	160	■	■		■		
S5.08	X	EP,PUR	Misc.	1	80		2	120	3	200	■			■		
S5.09	X	EP,PUR	Zn(R)	1	40		3	200	4	240	■	■	■	■	■	
S5.10	X	ESI		1	80		2-4	160	3-5	240	■	■	■	■	■	
S5.11	X	EP,PUR	Misc.	1	80		3	200	4	280	■	■	■	■	■	■
S5.12	X	ESI	Zn(R)	1	80		3	200	4	280	■	■	■	■	■	■
S5.13	X			1	80		2-4	240	3-5	320	■	■	■	■	■	■
S5.14	X	EP,PUR	Misc.	1	150		1	150	2	300	■	■	■	■	■	
S5.15	X			1-2	80		3-4	240	4-6	320	■	■	■	■	■	■
S5.16	X			1	250		1	250	2	500	■	■	■	■	■	■

The standard NORSOK M 501 specifies similar systems. For atmospheric exposure are 280 µm dictated and for permanent water exposure 350 µm. Please note, that NORSOK demands always minimum thicknesses, the ISO 12944 is talking about nominal thicknesses.

Illustration 4: Statement from NORSOK M 501, coating system 1, atmospheric exposure (excerpt).

<table>
<tr><th colspan="4">A 1. Coating system no. 1 (shall be pre- qualified)</th></tr>
<tr><th>Application (if not specified under others)</th><th>Surface preparation</th><th>Coating system</th><th>Minimum dry film thickness</th></tr>
<tr><td>Carbon steel with operating temperature < 120 °C

- Structural steel
- Exteriors of equipment, vessels, piping and valves (not insulated)</td><td>Cleanliness:
ISO 8501-1 Sa 2½

Roughness: ISO 8503 Grade Medium G (50 µm to 85 µm, Ry5)</td><td>1 coat zinc rich primer:

Minimum number of coats: 3

MDFT of complete coating system:</td><td>60µm

280µm</td></tr>
</table>

Illustration 5: Statement from NORSOK M 501, coating system 7, permanent immersion (excerpt).

<table>
<tr><th colspan="4">A 7. Coating system no. 7 (shall be pre- qualified)</th></tr>
<tr><th>Application (if not specified under others)</th><th>Surface preparation</th><th>Coating system</th><th>Minimum dry film thickness</th></tr>
<tr><td>Submerged carbon steel and carbon steel in the splash zone</td><td>Cleanliness:
ISO 8501-1 Sa 2½
Roughness: ISO 8503 Grade Medium G
(50 µm to 85 µm, Ry5)</td><td rowspan="2">Two component epoxy

Minimum number of coats: 2

MDFT of complete coating system:</td><td rowspan="2">350µm</td></tr>
<tr><td>Submerged stainless steel and stainless steel in the splash zone</td><td>Sweep blasting with non-metallic and chloride free grit to obtain anchor profile of approximately 25 µm to 45 µm</td></tr>
</table>

A typical coating system looks like (above waterline):

2 comp. epoxy-zinc rich primer		**50**	**-**	**80**	**µm**
2 comp. epoxy-mid coat	**in case 2 x**	**100**	**-**	**150**	**µm**
2 comp. polyurethane topcoat		**50**	**-**	**80**	**µm**
min. film thickness totally		**320**			**µm.**

Areas under water (e. g. mono piles):

2 - 3 x epoxy-coating	**225**	**µm each**
min. film thickness totally	**450**	**µm.**
	600	**µm (splash zone).**

For areas under water (immersion service) acc. to NORSOK cathodic protection has to be added to the coating system. Possibilities are installation of impressed cathodic corrosion protection or to weld on sacrificial anodes.

As summary can be written down that for corrosion protection at sea generally the same coating systems and coating materials can be used as for the protection of onshore windmills. They differ merely in film thickness and in case in number of layers. This statement is valid as from the beginning always only top quality products on basis of epoxy and polyurethane resins have been used for the protection of windmills.

In this connection we have to draw the attention already here to an important point regarding "offshore-corrosion-protection" in comparison to "onshore-corrosion-protection" for windmills.

ONSHORE	OFFSHORE
Generally cyclic bedew/ condensation without or with minor salinity.	Extended exposure to condensation combined with strong salinity and UV-light.
Moderate corrosion on holidays and weak areas of the coating. Around **50µm till 80µm** thickness loss of steel per m²/ year.	**Heavy corrosion** on holidays and weak areas of the coating. Around **200µm till 500µm** (splash zone) thickness loss of steel per m²/ year.

On basis of the described differences the simple but important conclusion is given that **qualified execution of the coating job is the decisive criterion** for successful "offshore corrosion protection". Some negligences and variations in quality, which are more or less normal in the daily business, can often be "tolerated" and they are normally without direct consequences for onshore windmills, but they cannot be tolerated in offshore service, as it would result in dramatic consequences. To highlight the quality assurance here a short review of a damage analysis.

Damage analysis,120 cases, Australia (Journal of Protective Coatings and Linings, January 2000)

	1983-1990 without ISO 9000	**1990-2000 with ISO 9000**
faulty coating material	2 %	2 %
wrong specification	19 %	41 %
changed environmental conditions	11 %	11 %
faulty processing/ wrong application	**68 %**	**46 %**

5. QUALIFICATION OF COATING SYSTEMS

In the field of "heavy corrosion protection" still dominate coating materials on basis of epoxy and polyurethane resins as they have proven their quality and they have impressive long-term references. Nevertheless, due to their extensive variety, especially for special ranges of applications and offshore belongs definitively to them, it is necessary to make a selection of coating materials by testing them in a careful way. Such tests comprise temporal stress for coating systems (short time tests) with a predefined definition of their condition before and after the tests. The judgement of damages of the coating systems due to their exposure to the different tests, is done visually and with instruments. Also here please refer to EN ISO 12944 and NORSOK M 501/ ISO 20340.

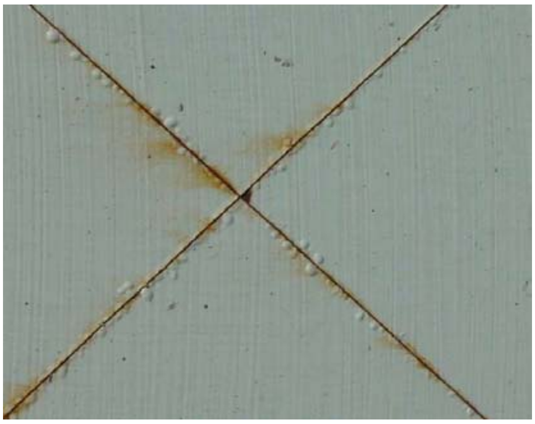
Examples of test for coating systems

EN ISO 12944, part 6		**NORSOK M 501/ ISO 20340**
onshore exposure corrosivity category C3	**offshore exposure corrosivity category C5M/ Im2**	**offshore exposure atmospheric/ immersion**
480h neutral salt spray (ISO 7253) 240h water condensation (ISO 6270)	1440h neutral salt spray (ISO 7253) 720h water condensation (ISO 6270)	1 cycle: 72h UV/ condensation test (ISO 11507) 72h neutral salt spray (ISO 7253) 24h low temperature exposure (-20°C) 25 cycles in total (4200h)
	3000h water immersion (ISO 2812-2), 1440h salt spray test (ISO 7253)	4200h water immersion (ISO 2812-2), plus 6 months cathodic disbonding (ISO 15711)

Typical evaluation criteria are mainly:
- degree of blistering and cracking (ISO 4628),
- degree of rusting and flaking (ISO 4628),
- degree of chalking (ISO 4628),
- adhesion (ISO 4624),
- corrosion creep from scribe.

For clarification some examples about test equipment and evaluation criteria:
Salt spray test (ISO 7253)

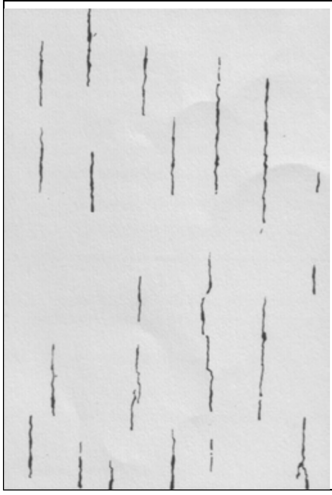
Corrosion creep from the artificial scribe



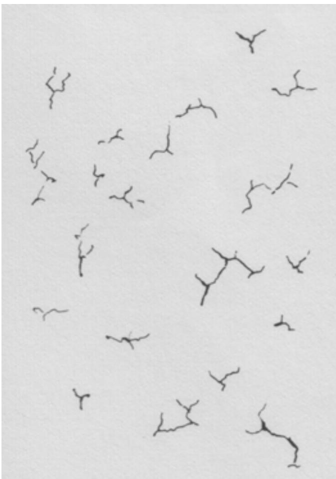
Equipment for testing of the resistance against UV- light exposure (QUV- test)

Statements from ISO 4628: Paints and varnishes - Evaluation of degradation of paint coatings - Designation of intensity, quantity and size of common type of defects (excerpts)

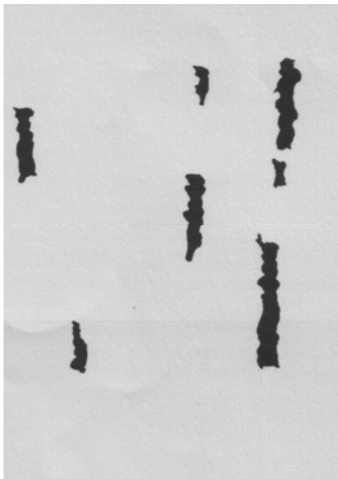
Cracking



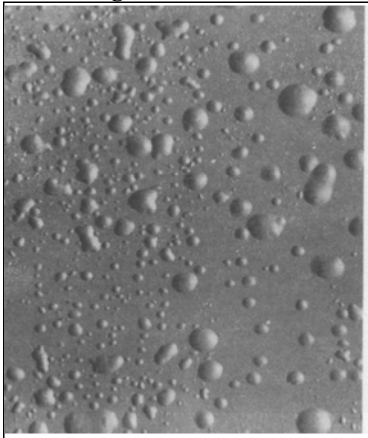
Cracking



Flaking

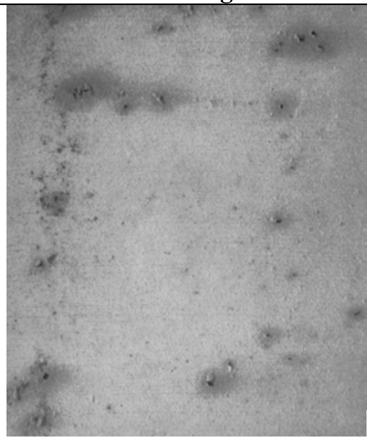


Blistering

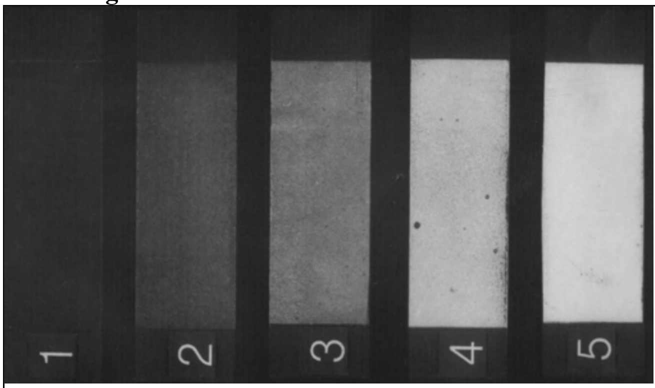


Blistering

Derusting



Chalking



6. REALISATION OF THE COATING JOB

Successfully passed tests are necessary but no alone an adequate criteria for successful corrosion protection and not at all for the requirements for "Offshore Service". Already during planning the steelworks corrosion protection suited design **must be** considered **(EN ISO 12944, part 3)**. All significant points have to be put into a specification, clear and without doubt **(EN ISO 12944, part 8)**. This specification must be distributed to all parties involved. All starts with the predefined existing rust grade of the steel to be used **(ISO 8501 / part 1, not worse than B)**. Furthermore must be specified how welding seams and sharp edges have to be prepared under the aspect of later coating treatment **(ISO 8501/3)**. Clear directions regarding cleanliness of the surface and roughness as well as execution and control of all steps o the coating job must be part of the specification **(EN ISO 12944, part 7)**.

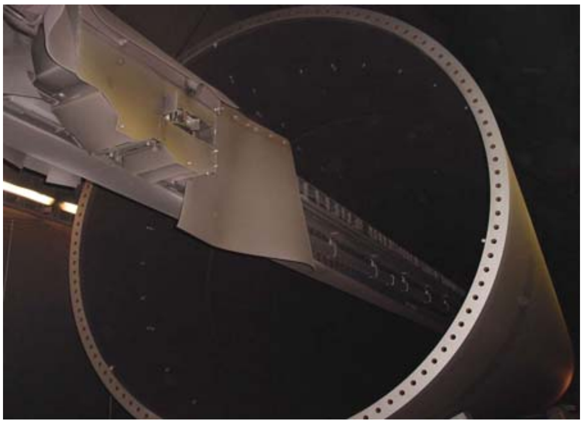
The lifetime of a coating system depends in general of five factors:

- Quality of surface preparation
- Actual obtained coating thickness
- Quality of workmanship
- Quality of the coatings
- Conditions at location

The red marked points lay in hands of the subcontractor and are always the decisive ones. Execution of the whole work according to existing technical standards, well organized quality assurance and external quality control are as experience shows essential prerequisites for successful implementation of all points given regarding corrosion protection.

Some pictures, which will make this clear.

Modern blast cleaning equipment (highly automated)



Modern application- and heatable drying cabins with very good lighting and access

Modern 2 component spray equipment (mixing unit, right: paint supply from containers)

A last hint. Besides qualified coating systems and execution of all coating jobs according to the best technical standards, especially in the offshore business, you should refer to experiences and references. The just shown examples of modern working conditions are not standard everywhere. The field of corrosion protection for windmills, especially for steel towers is today, more than ever before, marked by strong competition. Coating application around the clock, 24 hours every day, under pressure of time, carried out by foreign labourers with whom communication is often very difficult, are typical constellations for this business today. Therefore more and more comes the demand for faster drying of the coating, lower thicknesses and fewer layers. Does this make sense in every case?

Today it is possible to qualify 1- and 2-layer systems with partly reduced film thicknesses than mentioned before, for highest requirements. It is one thing to apply the very best coating under laboratory conditions onto perfect prepared test panels to expose these to the test. But it is a completely other thing to reproduce the same at site on thousands of square meters around the clock and sometimes under not always optimal conditions. In reality it is all much more complicated and can therefore not always been realized.
The more demanding a coating material is, the higher are the requirements during application and therefore much more responsibility is transferred to the applicator. This should be absolutely clear. Coating materials should therefore not only be customer oriented, they have to be versatile and they have to be able (in a certain size) to tolerate variations which occur in daily practice. Nothing else tells more about these remarkable points than practical references, preferably from the offshore-field.

As illustration finally some examples. All objects are protected by products which are still in use for windmills.

Windpark Vindeby (Denmark), 1991

Windpark Middelgrunden (Denmark), 2001

Windpark Tune Knob (Denmark), 1995

Windpark Horns Rev (Denmark), 2003

Windpark Utgrunden (Sweden), 2000

Windpark Samso (Denmark), 2003

West Alliance 2002, offshore rig
(Keppel Shipyard, Singapore)

Stena Don, offshore rig, 2001
(Kvaerner Warnow Shipyard, Germany)

<u>Specifications for steel towers for windmills and for the rigs West Alliance and Stena Don</u>

Tunoe Knob

outside:	80	µm	Metallization	inside:		40	µm	Epoxy zinc dust paint
	100	µm	Epoxy paint		2x	140	µm	Epoxy paint
	100	µm	Epoxy paint					
	50	µm	Polyurethane paint					

Vindeby

outside:	120	µm	Metallization	inside:		75	µm	Epoxy paint
	100	µm	Epoxy paint			150	µm	Epoxy paint
	100	µm	Epoxy paint					
	50	µm	Polyurethane paint					

Utgrunden

outside:	75	µm	Epoxy zinc dust paint	inside:		70	µm	Epoxy zinc dust paint
	2x110	µm	Epoxy paint			150	µm	Epoxy paint
	50	µm	Polyurethane paint					

Middel-grunden

outside:	100	µm	Metallization	inside:	80	µm	Metallization
	120	µm	Epoxy paint		100	µm	Epoxy paint
	100	µm	Epoxy paint		100	µm	Epoxy paint
	50	µm	Polyurethane paint				

Horns Rev

outside:	100	µm	Metallization	inside:	80	µm	Metallization
	100	µm	Epoxy paint		100	µm	Epoxy paint
	120	µm	Epoxy paint		100	µm	Epoxy paint
	50	µm	Polyurethane paint				

Samso

outside:	80	µm	Metallization	inside:	60	µm	Metallization
	120	µm	Epoxy paint	first 10m	200	µm	Epoxy paint
	100	µm	Epoxy paint	than	50	µm	Epoxy zinc dust paint
	50	µm	Polyurethane paint		100	µm	Epoxy paint

West Alliance 2002 and Stena Don

above waterline:	Epoxy zinc dust paint Epoxy paint Polyurethane paint	under water:	Epoxy paint

Cologne (Germany), August 2004

Karsten Mühlberg, HEMPEL (GERMANY) GmbH
Office West, Niederkasseler Straße 6, 51147 Cologne (Germany)
Phone:+49 (0) 2203 - 911 71-13, Fax: +49 (0) 2203 - 911 71-9, Mobile: +49 (0) 171-6712 200
E- mail: mue@de.hempel.com, www.hempel.com, www.hempel-germany.de